LLNL Environmental Restoration Division Standard Operating Procedure	TITLE: Borehole Sampling of Unconsolidated Sediments and Rock
APPROVAL **Date** _____ _____ **Livermore Site Deputy Program Leader**	**PREPARERS:** **J. Gardner*, S. Gregory, J. Hoffman*, and S. Nelson*** **REVIEWERS:** **R. Bainer, L. Berg*, T. Carlsen, R. Devany*, V. Dibley, and M. Dresen***
APPROVAL **Date** _____ _____ **Division Leader** **CONCURRENCE** **Date** _____ _____ **QA Implementation Coordinator**	**PROCEDURE NUMBER:** **ERD SOP-1.2** **REVISION: 2** **EFFECTIVE DATE:** **December 1, 1995** **Page 1 of 26**

*Weiss Associates

1.0 PURPOSE

To ensure acceptable, consistent procedures for collecting discrete soil and rock samples from the vadose zone and several water bearing zones in a single borehole while preventing or minimizing cross contamination of samples.

2.0 APPLICABILITY

This procedure is applicable for all personnel performing borehole sampling, and should be fully reviewed prior to conducting these activities.

3.0 REFERENCES

3.1 American society for testing and materials (1991), *Standard method for penetration test and split-barrel sampling of soils*, astm d: 1586-84, vol. 04.08, 232-237.

3.2 American society for testing and materials (1991), *Standard practice for diamond core drilling for site investigation*, astm d: 2113-83, vol. 04.08, 260-263.

3.3 American Society for Testing and Materials (1991), *Standard Practice for Ring-Lined Barrel Sampling of Soils*, ASTM D: 3550-84, Vol. 04.08, 445-447.

3.4 Dresen M. D. and F. Hoffman (1986), *Volatile Organic Compounds in Ground Water West of LLNL*, Lawrence Livermore National Laboratory, Livermore, Calif., July 1986, 46 pp. (UCRL-53740).

3.5 Hoffman, F. and M. D. Dresen (1989), *A Method to Evaluate the Vertical Distribution of VOCs in Ground Water in a Single Borehole*, Lawrence Livermore National Laboratory, Livermore, Calif., February 1989, 8 pp. (UCRL-100509, Preprint).

4.0 DEFINITIONS

4.1 Borehole

Any penetration of the ground surface created by drilling equipment.

4.2 Volatilization

The rapid loss of compounds through evaporation at ordinary temperatures.

5.0 RESPONSIBILITIES

Note: The following responsibilities (Sections 5.1–5.5) are listed by the appropriate level of authority to ensure that proper representation for all procedures and regulations related to this SOP are met.

5.1 Division Leader

The Division Leader's responsibility is to ensure that all activities performed by ERD at the Livermore Site and Site 300 are performed safely and comply with all pertinent regulations and procedures, and provide the necessary equipment and resources to accomplish the tasks described in this procedure.

5.2 Hydrogeologic Group Leader (HGL)

The HGL's responsibility is to ensure that proper procedures are followed for activities (i.e., drilling, borehole logging and sampling, monitor well installations and development) and to oversee the disposal of all investigation derived wastes.

5.3 Drilling Supervisor (DS)

The DS plans and coordinates all drilling related activities, ensures that all drilling related activities are performed safely and efficiently (using the proper procedures), and that the data generated from these activities are valuable and representative of the true geologic or physical conditions within the borehole. Such activities may include operation of logging equipment, soil sampling, well installation, and development. The DS is also responsible for:

5.3.1 Coordination of the drilling contractor schedules and equipment needs:

- Coordinate the schedules of multiple drill rigs with the drilling contractor.
- Provide the Work Plan to the drilling contractor and answer questions.
- Negotiate the arrival/start date and drill type.

- Monitor the progress of the drilling and anticipate changes in equipment needs (e.g., auger rig, air-mist rig, mud-rotary rig).

5.4 Drilling Coordinator (DC)

5.4.1 The DC provides the interface between the DS and the field activities including:

- Oversight of the Drilling Geologist (DG) and field activities.
- Coordinate the DG's work load.
- Obtain the necessary equipment, supplies, and release numbers from the Technical Release Representative (TRR) for the drilling contractor.
- Provide guidance and training.
- Inform the DG about procedural changes in areas related to drilling (e.g., changes in sampling requests, cuttings disposal issues, new forms, etc.).
- Provide technical input to the DG and Study Area Leader (SAL)/Facility Task Leader (FTL).
- Review borehole and geophysical logs.
- Monitor drilling progress on a daily basis.
- Interact with the Quality Assurance (QA)/Quality Control (QC) officer on drilling and soil sampling issues.
- Estimate the contaminants likely to be present, and the quantity of drilling spoils that may be generated.

5.4.2 During the startup of a new drilling phase, the DS works with the DC and SAL/FTL to:

- Create and finalize all related drilling documents (i.e., the Work Plan and Sampling Plan).
- Work with the SAL/FTL to establish drilling locations, schedules, and budgets for each well.
- Determine the protective equipment necessary for personnel in the field.
- Make well completion decisions and specify the well construction details from the SAL/FTL and Hydrogeologic Group Leader (HGL) input.
- Act as the liaison between the SAL/FTL and the DG.
- Coordinates all necessary biological/archeological surveys prior to drilling. Results of the surveys should be forwarded to the SAL/FTL and Environmental Chemistry and Biological Group Leader (ECBGL).

5.5 Drilling Geologist (DG)

The DG's responsibility is to ensure that drilling activities are carried out according to the specifications designated in the Work Plan, Sampling Plan, Site Safety Plan (SSP), Operation Safety Procedure (OSP), and Standard Operating Procedure (SOP). Additionally, the DG must oversee and document all aspects of the drilling/field investigation, including lithologic and geophysical data, well completion and

development specifications, activities of the drillers, sampling and workspace monitoring details. The DG is also responsible for:

5.5.1 Site Preparation and Supply Ordering. The DG must:

- Review the Work Plan prepared by the SAL/FTL and DC, and discuss any questions.
- Assemble all necessary materials, including personal protective equipment (PPE).
- Supply tracking and ordering requests.
- Confirm that all necessary security arrangements have been made to permit site access (e.g., schedule escorts, notify the building coordinator of planned activities, arrange for opening of locked gates).
- Confirm that utility locator and mud pit excavations (if necessary) have been arranged with the field personnel.
- Discuss LLNL site planning requirements and utility lines with field personnel and drillers before drilling begins.

5.5.2 Site Safety

- Supply the SSP, OSP, and SOPs to all workers who enter the drill site.
- Monitor and record work space conditions with appropriate monitoring equipment (including FID, PID, etc.) during drilling activity.
- Confirm that appropriate fencing, warning signs, barricades, animal exit ramps (for mud pit), borehole cover and protection are in place.
- Discontinue work and contact the DC if chemical or physical hazards are encountered.

5.5.3 Field Activities

- Coordinate schedules/actions with field personnel.
- Research site hydrogeology to estimate key parameters (e.g., sample target zones, hydrostratigraphic unit depths and thicknesses, and types of contaminants).
- Obtain a field logbook from the Data Management Group (DMG).
- Calibrate and record calibration information for all monitoring equipment.
- Confirm all sample naming conventions with DMG.
- Collect and document samples.
- Handle all changes and corrections to chain-of-custody (CoC) forms and/or analytical requests.
- Inform the DC, SAL/FTLs, and DMG of any sampling or sampling documentation irregularities.
- Report any deviations from the SSPs, OSPs, or SOPs to the QA/QC Officer.
- If SOPs are violated, a nonconformance report is to be completed and submitted to the QA/QC officer.

- Report missed turnaround times for analytical sample results to QA/QC Officer.
- Confirm that drilling waste analytical results are consistent with the chosen disposal method.
- Decontaminate all sampling equipment.
- Provide frequent updates and documentation of field activities to the DC, HGL, and SAL/FTL.

5.6 Environmental Chemistry and Biology Group Leader (ECBGL)

The ECBGL's responsibility is to provide biological or chemical information and expertise (i.e., biological surveys, water supplies, chemical field instruments, etc.).

5.7 Field Personnel

The field personnel's responsibilities are to conduct all ERD field work in a manner that complies with all established operational and safety procedures, and to inform the Hydrogeologic Group Leader (HGL) when the procedures are inappropriate.

Activities the field personnel are responsible to perform (but not limited to) are to:

- Collect, store, and ship borehole samples to analytical laboratories.
- Drill, complete wells, log boreholes, and properly develop wells to allow the highest yield and the highest quality samples possible.
- Communicate the performance of development activities to the DC to allow for modification of the development methods to improve well yield.

5.8 Site Safety Officer (SSO)

The SSO's responsibility is to receive the details of potential hazards and procedures for all field activities. The SSO directs this information to the LLNL Hazards Control Department to determine if a new OSP is required, thus assuring that an existing OSP addresses all ES&H issues for each operation.

5.9 Technical Release Representative (TRR)

The TRR is responsible for the acquisition and administration of blanket contract releases for the procurement of goods and services. The TRR has the authority to obligate LLNL for payment of goods and services, delegated by the LLNL Business Manager through the Procurement Department.

6.0 PROCEDURES

Borehole sediment and rock sampling is a useful technique for identifying/characterizing the geology, hydrogeology, and sources of contamination, and delineating contaminant distribution in both the saturated and unsaturated zones. It is very important that sampling procedures are followed rigorously so that consistent, high quality analytical data can be obtained. It is essential that the sampling process does not introduce hazardous or foreign substances into the borehole or sample. It is also desirable that the sampling techniques preserve the integrity of all chemicals of interest in their *in situ* concentrations. In practice, these goals may not be fully achieved because

the sample is inevitably disturbed somewhat by the mechanics of drilling, sampling, and handling.

Methods of sediment sampling include driving split barrel samplers and coring. To facilitate sampling for volatile organic compounds (VOCs) in the saturated zone of unconsolidated sediments, standard mud-rotary drilling is employed. A specialized sampling technique called "Depth Sampling" was developed at LLNL (Dresen and Hoffman, 1986; and Hoffman and Dresen, 1989), and is used extensively.

Use the Borehole/Well Construction Log (Attachment A) and the Soil Analysis Form (Attachment B) to document soil sampling. In addition, complete a chronology of daily events on the Daily Field Report (Attachment C).

6.1 Office Preparation

6.1.1 The DC must provide the TRR with an estimate of sampling requirements prior to obtaining a release number.

6.1.2 The DG should obtain materials listed in the Equipment Checklist (Attachment D).

6.1.3 The SAL,/FTL, DC, and DG should review existing geologic and hydrogeologic data and discuss sampling strategy with the ECBGL, the HGL, and/or the SSO, or their designee(s). The DG should obtain and fill out a Borehole Work Plan and Logging and Sampling Plan (Attachment E) and have it approved by the DS and ECBG.

6.1.4 The SAL, FTL, and DC should gather site hydrogeology information to estimate key parameters (e.g., sample target zones, depth and thickness, types and concentrations of contaminants, etc.).

6.1.5 The DS should coordinate schedules/actions with the DC, DG, and HGL.

6.1.6 The DG should obtain a Field Sampling Logbook to record sample numbers and Chain-of-Custody (CoC) document numbers per SOP 4.2, "Sample Control and Documentation."

6.1.7 The DG shall review appropriate SOPs and pertinent sections of the Site Safety Plan, and discuss the need for personal protective equipment with the SSO and the DC.

6.1.8 The DS shall ensure that expected conditions will be included in the drilling OSPs. Any expected or suspected conditions, either of a chemical or physical nature, which are not included in the drilling OSPs necessitate the production of an OSP addendum to address these issues.

6.2 Field Preparation

The following is to be performed by the DG and the drilling contractors.

6.2.1 Inventory all necessary items.

6.2.2 Decontaminate all sampling equipment prior to sampling a new borehole per SOP 4.5, "General Equipment Decontamination."

6.2.3 Follow the instructions pertaining to conducting field work per SOP 4.1, "General Instructions for Field Personnel."

6.3 Split-Barrel Sampling

6.3.1 Wash split-barrel sampler with detergent and water approved by the ECBGL, and rinse with clean water or de-ionized water, or steam clean per SOP 4.5, "General Equipment Decontamination." Collect a rinesate/equipment blank, from the interior of the sampler and submit for analysis per SOP 4.9, "Collection of Field QA/QC samples" deemed necessary by the DC or DS. The DC and or DS shall determine the necessity and frequency of equipment blanks during drilling activities.

6.3.2 Remove cuttings/slough from borehole and center plug.

6.3.3 Sample collection for volatile and semivolatile organic compound analysis.

A. Load precleaned (steam cleaned, de-ionized rinse) brass or stainless steel tubes into a split-barrel sampler. After the driller is certain all slough is removed from the auger and borehole, drive the sampler to desired depth in borehole.

B. To maximize sample integrity, collect the sample from the deepest tube, provided quality is good (i.e., no headspace).

C. Quickly observe lithology, seal the tube ends with Teflon tape, high-density polyethylene caps, and secure with duct tape.

D. Use an indelible marker to label the sample with identification (borehole/well number followed by top of sample depth), sampling date, sample time, analysis type(s), sample collector's initials per SOP 4.2.

E. Immediately place the sample tube in a plastic bag and seal by tying a knot in the opening. To keep samples dry, double bag. Double bag sets of samples when cross contamination is not a concern.

F. To facilitate rapid cooling, all samples should be placed in an insulated cooler containing loose ice. Ice melt water is to be drained from the cooler throughout the day, and all loose ice is also double bagged at the end of the day for courier delivery to the analytical laboratory. Blue Ice coolant packs should be used for shipping samples through the LLNL Shipping Department.

G. Document sample location, turnaround time, and analysis type(s) on the Borehole/Well Construction Log (Attachment A).

6.3.4 Sample collection for metal, high explosives (HE), and radiological analysis.

A. Load tubes into split-barrel sampler and drive sampler to desired depth in borehole. Stainless steel sample tubes should be used during metals sampling to prevent metal cross contamination.

B. Record lithology, seal the tube ends with Teflon tape, and secure with duct tape. Alternatively, sample can be transferred to a wide-mouth glass jar and sealed with duct tape.

C. Use an indelible marker to label the sample tube or jar with the identification (borehole/well number followed by top of sample depth), sampling date/time, sample analysis type(s), sample collector's initials per SOP 4.2.

D. Place the sample tube or glass jar in a plastic bag and refrigerate as described in 6.3.3.E.

E. If tritium analysis is to be performed, immediately refrigerate the sample tube or jar in plastic bags in an insulated cooler. If a jar is used, ensure that the jar is

packed tightly to reduce air space, and that the lid is closed tightly and taped to help seal. If the samples are not immediately shipped to the analytical laboratory, they should be stored in a refrigerator. Samples held for over 1 week will be transferred to a freezer.

F. Document sample location, turnaround time, and analysis type(s) on the Borehole/Well Construction Log (Attachment A).

6.4 Coring

6.4.1 Wash core barrel with detergent and water approved by the ECBGL, and rinse with clean water, or steam clean as per SOP 4.5. Collect a rinesate/equipment blank from the core barrel and submit for analysis as per SOP 4.9, "Collection of QA/QC Samples," when necessary.

6.4.2 Insert cleaned brass or steel tubes into the core barrel if samples for VOCs or similar compounds are to be collected.

6.4.3 Insert core barrel and core 5 ft or less.

6.4.4 Retrieve the core barrel with a wireline overshot device immediately, if possible.

6.4.5 Carefully, but quickly, remove the core from the core barrel, ensuring that the core remains in stratigraphic sequence.

6.4.6 Collection of samples for VOC analysis.

A. Quickly observe lithology. Wrap a core segment of lithified sediment or rock approximately 3 to 7 in. with inert plastic tubing in an air-tight plastic bag, or in a wide-mouth glass jar and seal with duct tape. Note: the sample must be packed tightly to reduce air space. Other acceptable sample containers are stainless steel or brass cylinder tubes. If these are used seal the ends with Teflon tape, cover with high-density polyethylene caps, and secure with duct tape.

B. Use an indelible marker to label the sample with identification (borehole/well number followed by top of sample depth), sampling date/time, analysis type(s), and sample collector's initials per SOP 4.2.

C. Immediately place the sample in a bag, and refrigerate in an insulated cooler (Section 6.3.3.E).

D. Document sample location, turnaround time, and analysis type(s) on the Borehole/Well Construction Log (Attachment A).

6.4.7 Collection of samples for metal, HE, and radiological analysis.

A. Record lithology, wrap a core segment of approximately 3 in. with inert plastic tubing, in an air-tight plastic bag, or in a wide-mouth glass jar, seal with duct tape. Note: the sample must be packed tightly to reduce air space. Other acceptable sample containers are stainless steel or brass cylinder tubes. If these are used, seal the ends with Teflon tape, cover with high-density polyethylene caps, and secure with duct tape.

B. Use an indelible marker to label the sample with the identification (borehole/well number followed by top of sample depth), sampling date/time,

sample analysis type(s), sample collector's initials, and LLNL/project name (optional).

C. Place the wrapped core segment, glass jar, or soil sample tubes in sealed bags and refrigerate as previously described in Section 6.3.3.E.

D. If tritium analysis is to be performed and samples are not shipped out immediately, samples should be transferred to a refrigerator at the end of the day, or a freezer if held for more than 1 week.

E. Document sample location, turnaround time, and analysis type(s) on the Borehole/Well Construction Log (Attachment E).

6.4.8 Store remainder of core in boxes per SOP 1.1, "Field Borehole Logging."

6.5 Depth Sampling—Livermore Site

"Depth Sampling" uses the mud-rotary drilling technique and a 94-mm wireline punch-coring system. This technique enables the collection of samples from several water-bearing zones in each borehole while preventing or minimizing cross contamination. The technique is utilized effectively when VOC concentrations are moderate to low (i.e., generally less than about 10 ppm). Attachment F is a schematic diagram of punch-coring and depth sampling that shows a water-bearing zone encountered after sampling and drilling through two "shallower" water-bearing zones containing VOCs. During the drilling a mud cake forms along the borehole sidewall, which restricts the water flow from the upper water-bearing zones into the hole. In addition, the relatively dense drilling mud penetrates the formation and further restricts water flow into the borehole from the formation. These effects tend to isolate and therefore "protect" deeper water-bearing zones from the VOCs. The following procedures are used:

6.5.1 Only pure (i.e., non-beneficiated) bentonite and potable water from source(s) approved in advance by the project ECBGL are to be used.

6.5.2 Upon encountering a new water-bearing zone, the sampler is removed with a wireline while the drill rod remains in the borehole, and new mud is mixed in a dedicated tub. The new mud, pumped into the drill rod, displaces the old drilling mud, which may contain VOCs, into the annular space outside of the drill rod (Attachment F). The mud tub at the surface collects the spent mud and, subsequently, the cleaned core barrel, lined with previously steam-cleaned brass or steel tubes, per SOP 4.5, is deployed through the new drilling mud to prevent contamination of the sampling equipment with VOCs that may have been in the previous drilling mud.

6.5.3 Core drill 1 to 2 ft to collect a sample of the sediment for chemical analysis (Attachment F).

6.5.4 Retrieve the core barrel with a wireline overshot device.

6.5.5 To minimize potential displacement of pore water in the sample, retain the bottom-most tube for chemical analysis. If significant void space or drilling mud penetration is evident, discard the sample and collect and retain the next suitable sample.

6.5.6 Permeable lenses (<3 ft thick) may be sampled by quickly "stuffing" sediment core into a brass sample tube and noting the location on the borehole log.

6.6 Field Post Operation

6.6.1 Collect, inventory, and prepare all samples for shipment, per SOP 4.4, "Guide to the Handling, Packaging, and Shipping of Samples".

6.6.2 Fill out CoC forms and shipping forms per SOP 4.2.

6.6.3 Decontaminate all equipment per SOP 4.5.

6.6.4 Record a daily summary of drilling and sampling in the Field Sampling Logbook per SOP 4.2, and on the Daily Field Report (Attachment C).

6.7 Office Post Operation

6.7.1 Deliver all original forms and logbooks to the DMG for storage.

6.7.2 Provide the DC copies for review and distribution.

7.0 QUALITY ASSURANCE RECORDS

7.1 Borehole/Well Construction Log

7.2 Chain-of-Custody Form

7.3 Document Control Logbook

7.4 Daily Field Report

7.5 Soil Analyses Form

7.6 Borehole Logging and Sampling Plan

8.0 ATTACHMENTS

Attachment A—Borehole/Well Construction Log

Attachment B—Soil Analyses Form

Attachment C—Daily Field Report

Attachment D—Equipment List

Attachment E—Borehole Work Plan and Logging and Sampling Plan

Attachment F—Schematic Diagram of Depth Sampling and Punch Coring

Attachment A

Borehole/Well Construction Log

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BOREHOLE / WELL CONSTRUCTION LOG

Page ____ of ____

BOREHOLE LOCATION	Project:	Borehole / Well No:
		Job No:
	Logged By:	Edited By:
	Project Manager:	Drill Rig:
	Drilling Contractor:	
	Driller / Helper:	
	Drilling Method:	Sample Method:
	Hammer Weight / Drop:	Bentonite / Gel Product Used:
	Borehole Diameter, Pilot:	Final:
	Borehole Started, Time / Date:	Borehole Completed, Time / Date:
	Well Started, Time / Date:	Well Completed, Time / Date:
Notes:	Water Depth	
	Boring / Casing Depth	
	Time	
	Date	

Total Depth:	Casing Depth:
Screened Interval:	
Sand Pack, #3:	#0:
Well Development Method:	
Time: Date:	Flow Rate:
Geophysical Logs, Type:	
By:	Date:

OVA / PID Field Readings (ppm)																
Work Area	Soil / Rock	Sampler Type / Depth	Blows / 6 Inches for RQD	Inches Driven / Inches Recovered	Sample Condition / Time	Sample ID / Depth: _____ Depth F	Analysis	Outer Annulus	Conductor Casing(s)	Well Annulus / Borehole Filler	Well Casing	Depth in Feet	Recovery / Sample Loc.	Contact	LITHOLOGIC DESCRIPTIONS	
												1				
												2				
												3				
												4				
												5				
												6				
												7				
												8				
												9				
												10				

ERD-S3R-92-0010A

Attachment A. Borehole/Well Construction Log.

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BOREHOLE / WELL CONSTRUCTION LOG (cont.) Page ____ of ____

OVA/PID Field Readings (ppm)																
Work Area	Soil/Rock	Sampler Type/Depth	Blows / 6 Inches for RQD	Inches Driven / Inches Recovered	Sample Condition / Time	Sample ID/Depth: ____ Depth F	Analysis	Outer Annulus	Conductor Casing(s)	Well Annulus/ Borehole Filler	Well Casing	Depth in Feet	Recovery / Sample Loc.	Contact	Project / Job No.:	Borehole/Well No.:
															Notes:	
												1				
												2				
												3				
												4				
												5				
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												6				
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												8				
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												0				

ERD-S3R-92-0010B

Attachment A (Continued).

Attachment B

Soil Analyses Form

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Initials _____
Job No. _____

Saturated Soil Analyses from Boring B-___

Page ___ of ___

Sampling Date	Depth (ft)	Water-Bearing Zone	Soil Type (USC)	Sample Quality (P,F,G,E)	Analytic Method	Turn-around Time	TCE	PCE	1,1-DCE	CCl_4	mg/kg (ppm)					Lab Log No.	Bulk Density (g/cm^3)

Other Bulk Density Samples Available _____
TOC Samples Available _____

4/29/87

Procedure No. ERD SOP-1.2	Revision Number 2	Effective Date December 1, 1995	Page 15 of 26

Attachment C

Daily Field Report

DAILY FIELD REPORT

Date:	Project(s):
Name:	Project Manager:
Vehicle:	Job Number:

PID/OVA Calibration: Yes_____ No_____	Daily Site Safety Meeting Time:________
Time:________	

Time	Activity

jcm

Page __ of __

Attachment C. Daily Field Report.

Attachment D

Equipment Checklist

EQUIPMENT CHECKLIST

_____ Sample containers/labels
_____ Appropriate clothing (i.e., coveralls, steel-toed safety shoes, gloves)
_____ Company ID sign for vehicle (if applicable)
_____ Field forms (i.e., CoC form, Borehole/Well Constructions form)
_____ Any applicable permits
_____ Field notebook
_____ Hard hat
_____ Safety glasses
_____ Cooler with ice
_____ 300-ft weighted tape
_____ Rock hammer
_____ Steel measuring tape with engineering scale
_____ Steel spatula
_____ Hearing protection
_____ Core boxes and trays, indelible marking pens
_____ Water-level meter
_____ First aid kit
_____ Fire extinguisher
_____ Detergents (Alconox, TSP)
_____ De-ionized water
_____ Buckets and brushes
_____ Document control logbook
_____ PID or FID
_____ Barricades
_____ Signs listing responsible persons (if applicable)
_____ Caution tape
_____ Brunton Compass
_____ Measuring wheel
_____ Munsell soil color chart
_____ Sampling gloves (vinyl and nytrile)
_____ Duct tape
_____ Soil sample tubes
_____ Glass jars
_____ Aluminum foil
_____ Teflon tape (4 in. width)
_____ Bailers (Teflon or stainless steel)
_____ Drums
_____ Sampling Plan
_____ SSP/OSP

Attachment E

Borehole Work Plan and Logging and Sampling Plan

DATE

TO: Drilling and Supervising Geologists
FROM:
SUBJECT: Work plan for drilling boreholes

This work plan describes activities related to the planned borehole(s) / well(s) in the table below. Monitor well completion details will be determined by the drilling supervisor and project manager based on analytic and hydrogeologic information collected during drilling.

Borehole/well name	Purpose

Site Geology and Hydrogeology

Table 1. Units expected to be encountered.

Geologic unit	Approximate depth	Anticipated hydrogeology

Table 2. Information from nearby wells. See attached map for locations.

Well	Well depth (ft)	Approximate depth to water (ft)	Screened stratigraphic Unit	Completion depth (ft)	Maximum concentrations in ground water (ppb)

Drilling Methods and Procedures
- Drill with hollow-stem augers at least 5 ft into hard rock.
- Install surface casing after penetrating 5 ft of rock if required for borehole stability,
- Continue boreholes through hard rock to a maximum depth of 55 ft using 94-mm wireline coring. Total borehole depth will be determined by the DS and PM.
- If water is encountered, continue drilling 3 to 5 ft into the next fine-grained sequence. Contact the DS and PM to discuss well completion.

Sampling
- Samples will be collected at least every five feet and at lithologic changes. A sample from each interval will be analyzed for VOCs by EPA Method 8010.
- Several samples will also be analyzed for metals, petroleum hydrocarbons, high explosives, nutrients (nitrates), and radioactivity as described in the attached sampling plan(s) .
- After reviewing analytical results from the first borehole, the DS and PM may revise the sampling plans for the remaining boreholes.

DNAPL Testing
- A field test for DNAPLs should be performed if (1) abnormally high hits of VOCs are identified by PID, (2) an odor is evident, or (3) high VOC concentrations are expected based upon results of SVS sampling or previously drilled boreholes. A protocol for this procedure is being prepared by Stephen Vonder Haar.

Geophysical Logging
- Natural gamma, electromagnetic induction, and caliper logs may be run on each borehole as deemed appropriate by the DS and PM.

Monitor Well Installation
- Monitor well installation decisions will be made by the DS and PM based on evaluation of any encountered ground water zones.
- The regulators must approve well design before well installation can begin.

Site-Specific Issues
- Screen drilling fluids and cuttings daily as described in "Field Screening of Drilling Waste for Purgeable Halocarbons (TCE, PCE, DCE, etc.)."
- Because drilling will take place in a limited area, personnel without L or Q clearance must be escorted on site.
- Consult the SOPs for elaboration on any of the procedures described in this work plan.

Figure(s), Sampling Plan(s), and Other References
- Map of Proposed Borehole Locations (Figure 1)
- Sampling Plan(s)

Refer also to documents listed below:
- Field Screening of Drilling Waste for Purgeable Halocarbons (TCE, PCE, DCE, etc.).
- SOPs Applicable to 832 Canyon OU Characterization Plan Activities
- SOPs for Segregation of VOC-Contaminated Drilling Spoils at LLNL Site 300
- General Site Procedures

BOREHOLE LOGGING AND SAMPLING PLAN

Drilling Geologist/Engineer _____ **Drilling Geologist/Engineer** _____

Estimated Borehole Depth _____ **Start Date/Time** _____

Purpose(s) _____

Location _____

DRILLING METHOD

Unsaturated Zone		**Saturated Zone**
_____		**Air Rotary**
_____		**Mud Rotary**
_____ **Other** _____		_____ **Other** _____

LITHOLIGIC SAMPLING AND LOGGING (check appropriate items)

Unsaturated Zone

_____ **Log by cuttings, fluid pressure, driller input, etc. only (no lithologic sampling) from** _____ **to** _____ **ft**

_____ **Limited lithologic sampling: Collect samples from** _____ **to** _____ **ft or** _____

_____

_____ **Sample approximately every 10 ft and at material changes: log by cuttings between samples**

_____ **Other:** _____

Saturated Zone

_____ **Log by cuttings, fluid pressure, driller input, etc. only (no lithologic sampling) from** _____ **to** _____ **ft**

_____ **Limited lithologic sampling: Collect samples from** _____ **to** _____ **ft or** _____

_____

_____ **Sample approximately every 10 ft and at material changes: log by cuttings between samples.**

_____ **Continuously core**

_____ **Run routine suite of geophysical logs (natural gamma, caliper, spontaneous potential, point resistivity and 6 ft lateral**

_____ **Other:** _____

CHEMICAL SAMPLING (check appropriate items)

Unsaturated Zone

_____ **No chemical sampling**

_____ **Sample at about** _____

_____ **ft**

for the analyses listed in Table 1

Saturated Zone

_____ **No chemical sampling**

_____ **Sample ALL water-bearing zones for the chemical analysis list in Table 2**

_____ **Sample ONLY the following water-bearing zones for the chemical analyses listed in Table 2**

_____

_____ **Sample confirming layers between water-bearing zones as described below for the chemical analyses listed in Table 2** _____

_____

_____ **Other:** _____

Table 1: Unsaturated Soil Samples

Sample depth (ft)	Turnaround Time: R = Rush H = Hold N = Normal	Analytical laboratory	Type of analysis

Special instructions:

Table 2: Saturated Soil Samples

Sample depth (ft)	Turnaround Time: R = Rush H = Hold N = Normal	Analytical laboratory	Type of analysis

Special instructions:

Sampling Plan Approved by:

Hydrogeologic Group Leader

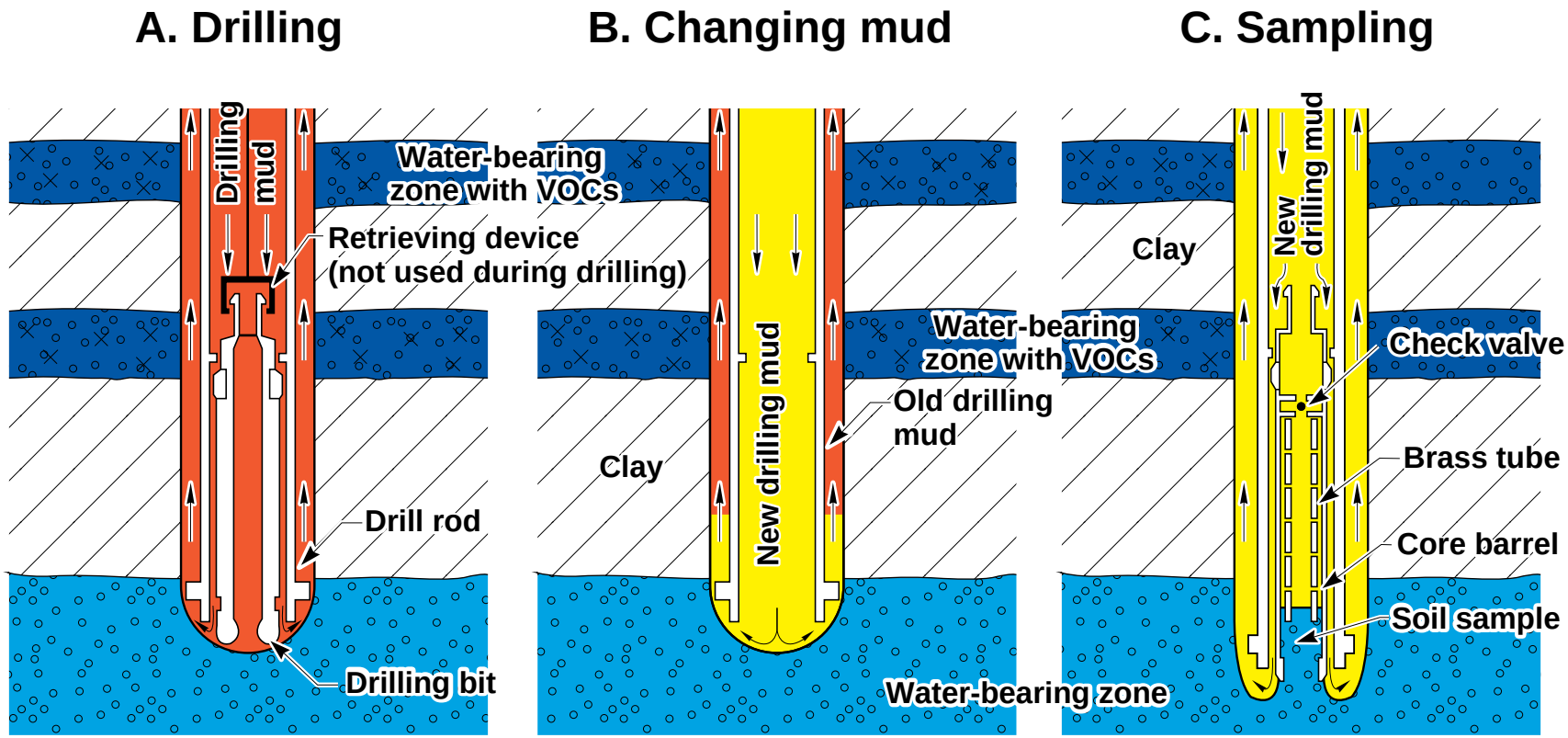
Initials/Date

Environmental Chemisry and Biology Group Leader

Initials/Date

Attachment F

Schematic Diagram of Depth Sampling and Punch Coring



Attachment F. Schematic diagram of depth sampling and punch coring (Dresen and Hoffman, 1986). Arrows indicate direction of mud circulation.